STATUS OF THE COOLER SYNCHROTRON COSY-JUELICH AND FUTURE PLANS

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Abstract

The cooler synchrotron COSY delivers unpolarized and polarized protons and deuterons in the momentum range 300 MeV/c up to 3.70 GeV/c. Electron cooling at injection momentum and stochastic cooling covering the range from 1.5 GeV/c up to maximum momentum are available to prepare high precision beams for internal as well as external experiments in hadron physics. The beam is fed to external experiments by a fast kicker extraction or by stochastic extraction.

In particular results of recent runs with the beam stabilizing transverse feedback system for intense electron cooled beams are reported. Future plans are briefly discussed.

INTRODUCTION

The accelerator facility [1,2] consists of the injector cyclotron JULIC, the synchrotron and storage ring COSY with 184 m circumference and experimental areas. Unpolarized and polarized protons and deuterons are accelerated in the momentum range from 300 to 3650 MeV/c. The floor plan of COSY with its 4 internal and 3 external experimental areas is shown in figure 1.

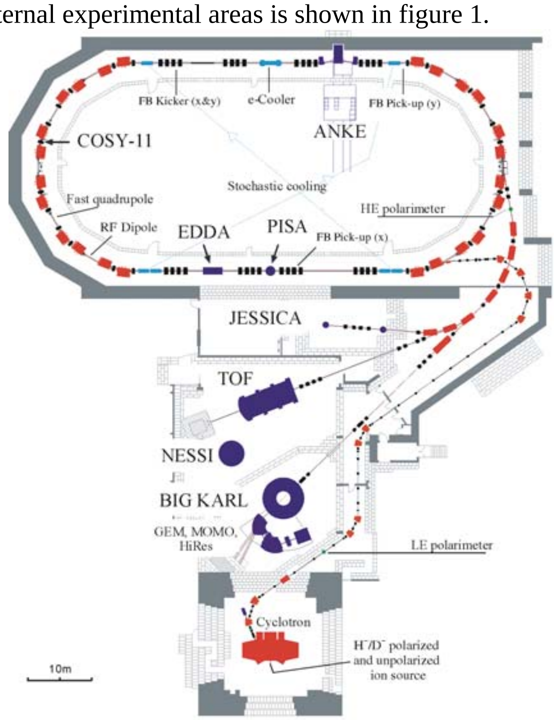

Figure 1: The COSY floorplan

The main topic of research is the production and interaction of strange mesons close to production threshold. Increasing the phase space density by electron cooling at injection momentum and conservation of beam emittance during experiments on the circulating beam (internal) at high momenta by use of the stochastic cooling system are the two outstanding features of COSY.

BEAM TIME STATISTICS

COSY has improved its running over the 11 years of operation from 3500 h per year in 1993 up to 7500 h in 2003. The reliability of COSY increased from 80 % in the first year of operation to more than 90 % in the last years. Approximately 2/3 of the year is dedicated to user operation. Figure 2 shows the beam time distribution during the year 2003.

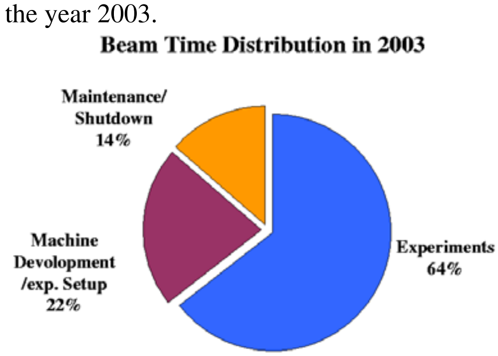

Figure 2: Beam time distribution

In the first years of COSY operation, only unpolarized protons were requested by the experiments. This has changed over the years, as the demand for polarized proton and deuteron beams increased. Unpolarized deuterons were available first for the MOMO collaboration in the beginning of 2002. Polarized deuterons with different combinations of vector and tensor polarization were successfully delivered to the experiments in 2003 (Figure 3).

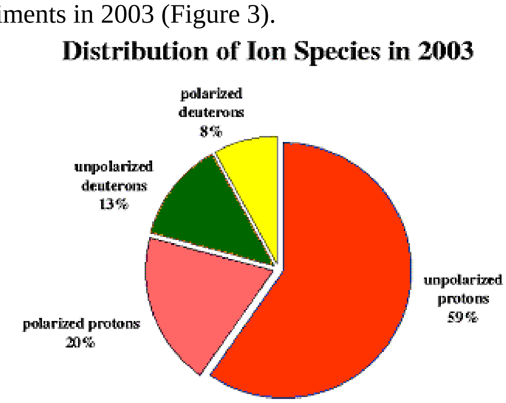

Figure 3: Beam time distribution among the ion species

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Table 1 shows a summary of the different operation modes and ion species with the achieved particle intensities after acceleration.

Table 1: Particle intensity of the accelerated beam for the different ion species and operation modes

Unpolarized Protons	Single injection	$1.4*10^{11}$
	Single injection with electron cooling	$1.5*10^{10}$
	Multiple injection with electron cooling and stacking	$5.0*10^{10}$
Polarized Protons	Single injection	$1*10^{10}$
	Single injection with electron cooling	$5.0 *10^{9}$
	Multiple injection with electron cooling and stacking	$1.2*10^{10}$
Unpolarized Deuterons	Single injection	$1.3*10^{11}$
	Single injection with electron cooling	$4*10^{10}$
Polarized Deuterons	Single injection	$6*10^{9}$

BEAM FEEDBACK AND STACKING

The intensity of the electron cooled coasting ion beam at COSY is limited by two different particle loss mechanisms [3]. The interplay of the electric field of the electron beam and ions with large betatron amplitudes passing the cooler section outside the electron beam is assumed to be responsible for incoherent losses directly after injection. Particle losses after several seconds of cooling are due to coherent transverse beam oscillations. These oscillations are caused both by the increase of the space charge impedance and the weak Landau damping due to the small momentum spread of the cooled beam [4]. Fig. 4 shows the beam current signal indicating incoherent losses directly after injection and coherent losses after 20 s together with beam position monitor (BPM) Δ-signals indicating horizontal and vertical oscillations.

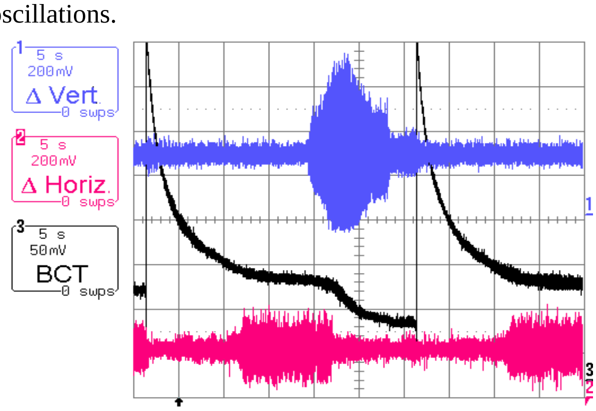

Figure 4: Beam behaviour during electron cooling. The beam current transformer (BCT) signal (black) is plotted together with horizontal (red) und vertical (blue) BPM Δ-signals. Time scale is 5 s/div

The dominating particle loss is due to the vertical oscillation because of the larger amplitude and the smaller aperture of the vacuum chamber.

A transverse feedback (FB) system, also called damper, makes it possible to damp coherent beam oscillations without any change of the machine optics [5]. BPM Δ-signals in the frequency domain (Fig. 5) and the beam current signal (Fig. 6) illustrate the performance of the FB system in the vertical plane.

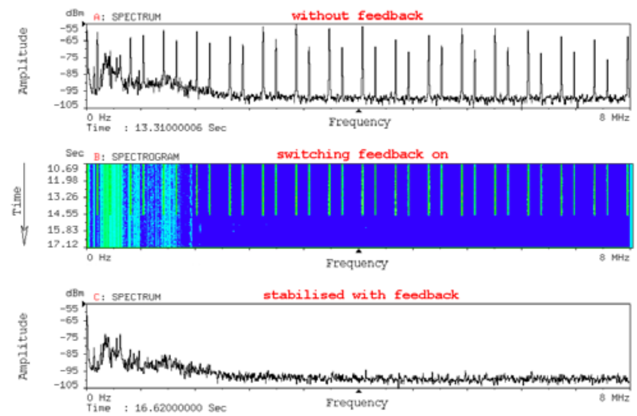

Figure 5: Fast Fourier transform of the vertical BPM Δ-signal of the electron cooled coasting proton beam at injection energy without FB (spectrum A), switching vertical FB on (spectrogram B), FB is on (spectrum C)

Without FB, betatron sidebands corresponding to the vertical coherent beam oscillation are observed. Switching the FB on makes them disappear.

Another very useful application of the FB system is stacking [2] the electron cooled ion beam by repeated injections (Fig. 7) to increase the intensity. In the case of stacking the beam of a single injection is cooled by the electron cooling system for two seconds. Then the closed orbit of the stored beam is again moved close to the stripper foil without loosing the cooled stored beam, and a new injection takes place, adding intensity to the stored beam. This procedure can be repeated many times to increase the total intensity of the stored beam while the electron cooler operates continuously.

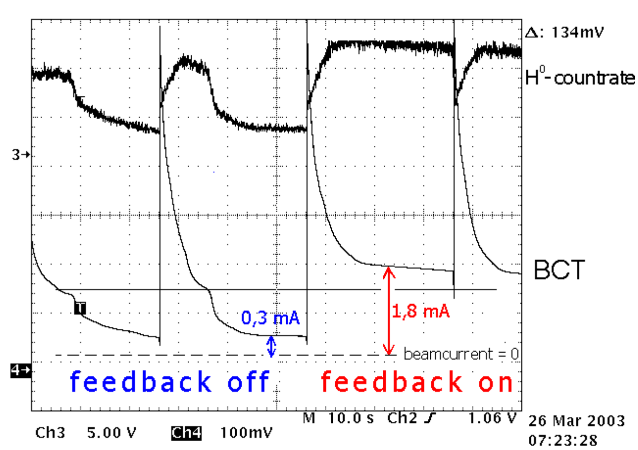

Figure 6: BCT and H^0-countrate signals without FB and with FB switched on. Time scale is 10 s/div

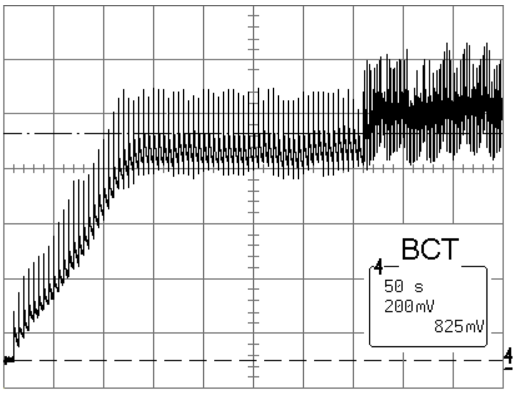

Figure 7: BCT signal during stacking of the cooled proton beam with active vertical FB. Time scale is 50 s/div. Intensity scale is 200 mV/div (2 mA beam current)

The vertical FB system made it possible to stabilise the cooled proton beam at a level of $2*10^{10}$ particles (1.8 mA) after a single injection. With the stacking technique a maximum of $1.2*10^{11}$ cooled protons (9.2 mA) at injection energy.

In September 2004 the horizontal FB system was successfully commissioned.

The intensity of single injected uncooled polarized beams in COSY is limited to approximately $1*10^{10}$ particles, because of the lower intensity of the polarized beam available at injection. However, due to the short beam lifetimes at injection energy and the long cooling time (several seconds), the intensity of the beam is reduced by approximately one order of magnitude. To increase this intensity, stacking injection is applied. By use of the vertical FB it was possible to reduce the particle losses and increase the intensity of the stacked beam to $1.2*10^{10}$ stored polarized protons. In particular for the TRIC experiment 15 injections with 4 s. intervals are stacked using electron cooling (I_e=170mA) and vertical FB giving $8*10^9$ polarized protons in flat top at 1.692 GeV/c. The flat top time is 1 hour.

FUTURE PLANS

The electron cooling at COSY (electron energy 25-100 keV) corresponds to proton energies up to 184 MeV. Electron cooling at electron energies of about 2 MeV [6] is considered as a necessary intermediate step towards the electron cooler, foreseen for the High Energy Storage Ring (HESR) of the GSI Darmstadt future accelerator project. Thus it will play a central role in conjunction with the involvement of the Forschungszentrum Juelich, Institute of Nuclear Research in designing and building the HESR. It will also be a good use for fast compensation of beam heating by high-density internal targets at COSY.

Further improvements are also planned for the experimental facilities, e.g.:

ANKE: installation of spectator detectors and polarized target (atomic beam source plus storage cell

TOF: implementation of a silicon microstrip telescope, a straw tube tracker in vacuum and frozen spin polarized target

WASA: transfer of the WASA detector from CELCIUS (Uppsala, Sweden) to COSY [7].

For the electron cooler and WASA detector installation additional funding is needed.

SUMMARY

COSY is a unique accelerator in the medium energy range for polarized and unpolarized beams of protons and deuterons. It delivers beam to users for over 5400 hours per year with a high reliability of more than 90 %. During 2003 the availability of polarized deuteron beams with different combinations of vector and tensor polarization for experiments at the COSY accelerator facility was added. A transverse feedback system is very useful when fighting coherent beam oscillation. Since it does not affect the tune it can be turned on and off without any changes in the machine optics. Installing the vertical and horizontal dampers at COSY gave significant intensity increase at single injection and the possibility of stacking electron-cooled beams. Future plans are the design of a 2 MeV electron cooler and installation of the WASA detector in COSY.

ACKNOWLEDGEMENTS

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